heated under its center. The water in the pan then begins to circulate. It becomes warm in the center, rises to the surface, spreads out to the sides of the kettle where it is cooled, and sinking follows the bottom back to the center. (See fig. 6.)

way of the North Sea these Norwegian falling storms would evidently become of much greater intensity and longer duration. We thus see how considerable is the influence of topography on the occurrence of storms.

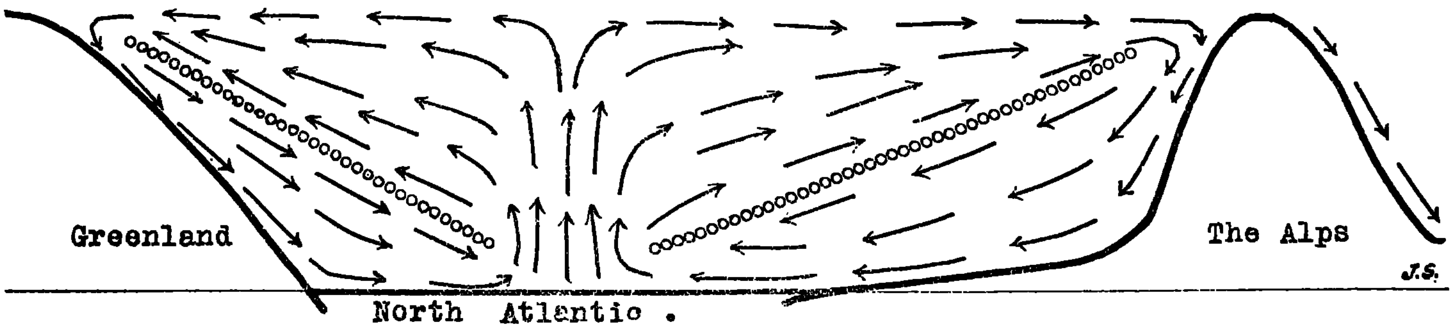

FIG. 6.—Vertical section through the atmospheric circulation over the North Atlantic in winter.

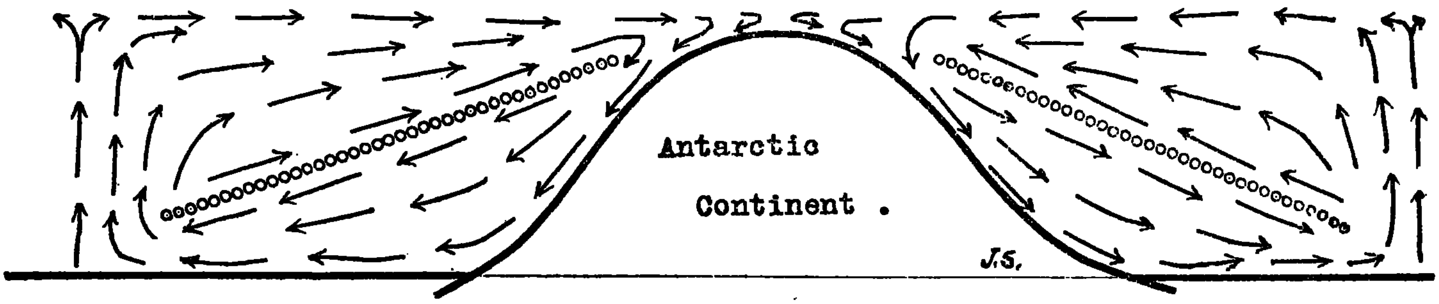

FIG 7.—Vertical section through the atmospheric circulation about Antarctica during the southern winter.

We find another condition in the South Polar region. Here the cold mountains are at the center, surrounded by the warm sea. But here also the rule holds that the air from the cold continent flows outward on all sides, following the surface. On the surrounding oceans the air is warmed and saturated with water, after which it rises and moves along the higher levels to Antarctica whose ice fields are fed by its moisture. (See fig. 7). The extraordinarily constant southwest wind which the Swedish South Polar Expedition of 1902–1903 met with here during the antarctic winter, maintained for weeks a velocity of 20 to 30 meters per second and indicates that the cold seaward-moving air current must be of great depth and strength.

We should then notice somewhat the details of figure 4. We see how the southeasterly air current prefers the easiest way across the North Sea and how it curves around the south end of mountainous Norway. In the narrow passage between Norway and Scotland the air movement is strongly accelerated. On the east side of the Scandinavian mountain range the heavy cold air piles up and forms a sort of aerial lake, with small velocities generally directed eastward. However, in the middle of this extended mountain range at Storlien, where its summit is lowest, the air flows westward from the east side of the ridge also. Evidently here the continental air overflows the ridge. Sometimes probably a portion of the cold-air sea dashes over the higher part of the range also and rushes down the west side of the mountains. These are the times of the extraordinarily violent easterly storms which I have met with in that region in winter and which stopped just as suddenly as they started.[4] Were it not for the open sluice-

[4] *Sandström* in Bull. Mt. Weather Observatory, Washington, 1912, **5**: 84-85.—EDITOR.

Many other important conclusions may indeed be drawn from the map in figure 4. What has already been done should be sufficient to awaken in the reader interest for a rational method of working up wind observations in different countries and at different seasons. This is the object of the present paper.

WATERSPOUTS OBSERVED OFF CAPE SAN LUCAS.

By WILLARD J. FISHER.

[Dated: New Hampshire College, Durham, N. H., Nov. 27, 1915.]

The following is an extract from my log on a voyage from New York to San Francisco last summer [1915] on the steamer *Kroonland*. The directions are approximate compass directions, taken with a pocket compass on the bows of an iron ship. Unfortunately, my supply of photographic films was exhausted and I could take no pictures. The sketches, figures 1 to 3, were made in my log immediately after dinner on the day of the observation; faithful tracings of them are reproduced here.

July 22, 1915:
$\phi=17°40'$ N., $\lambda=102°36'$ W. at noon.

July 23, 1915:
$\phi=20°46'$ N., $\lambda=107°36'$ W. at noon.

Crossing the broad entrance to the Gulf of California. Saw, 9 a. m. to 11:30 a. m., two long banks of clouds, extending N.-S. clear out of sight, moving about W., as they were several miles apart and they were caught up with, but only slowly. They were cumulus clouds; a section looked about like that shown by figure 1, which is looking northward. The air currents which fed them seemed to move as the dotted arrows. From below there hung down tornado funnels of various sizes and various stages of development, from mere pimples to long well-grown vortices; but none of them reached more than halfway to the sea. From one cloud a smart shower fell on us as we passed under. The funnels were formed where the upward growth of the bank was particularly vigorous; at such a place there might be a good many or a few or but one; the fewer, the bigger and better developed. They grew downward toward the sea from the cloud base in all cases.

FIG. 1.—Cumulus cloud with whirling mist filament, *x*, seen at entrance to Gulf of California, July 23, 1915.

I had a chance to see one very well. It lay like the arrow in figure 1, about which I have drawn a spiral line. (Fig. 1, *x*.) With the glass I could see the whirling filaments of mist, but they were not dense enough so that I could tell on which side they were, the near or the far, and so determine the direction of the rotation. The pattern was something like that shown in figure 2.

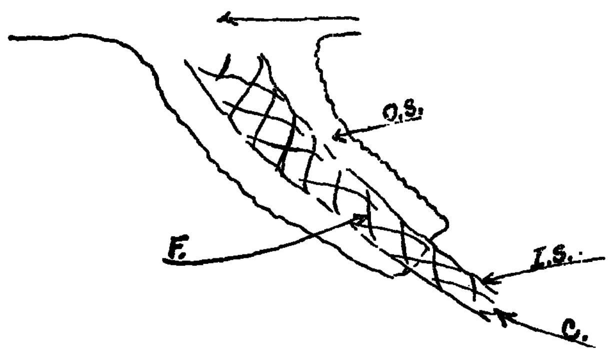

FIG. 2.—Details of the whirling mist filament of figure 1: Upper arrow shows westward direction of motion of the cumulus. *OS*, the outer less dense sheath, growing downward and following the inner sheath, *IS*. The external outline of *OS* was quite vague. *IS*, inner dense sheath, growing downward more rapidly than *OS*. *C*, the hollow empty core. *F*, mist filaments whirling and ascending, seen one through the other so as to give a lattice pattern.

Some of the funnels were so near the rear edge of the cloud as to be illuminated by sunshine; most were in shade, particularly the one above sketched was. The variations in form were from that of "A" to that of "B" in figure 3. Incipient forms were mere protuberances on the cloud base.

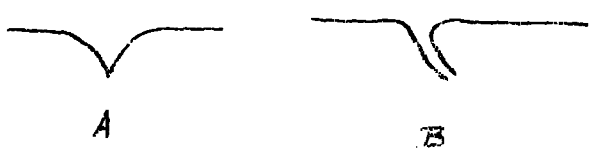

FIG. 3.—Limiting forms of whirls under cumulus clouds. A, seen from ahead of the cloud; very large, and reaching one-fourth of the vertical distance to the waves.

These two cloud banks seemed to join in a great cumulus bank far to the south.

July 24, 1915:

$\phi=24°12'$ N., $\lambda=112°14'$ W., at noon.

The dotted lines in the first figure were drawn from a comparison of the motion of mist wreaths in the clouds and the way the various tornado funnels lay below the clouds; they could not, of course, be drawn from direct observation.

I also saw a perfectly developed waterspout in the neighborhood of San Salvador [$?\phi=0°$, $\lambda=91°$ W. ?].

CIRCULATION AND TEMPERATURE OF THE ATMOSPHERE.

By WILLIAM HENRY DINES, B. A., F. R. S.

[Dated: Meteorological Office Observatory, Benson, Wallingford, England, Nov. 1, 1915; received Nov. 17, 1915.]

Meteorology has made great progress during recent years and many of the ordinary phenomena connected therewith have met with simple and satisfactory explanations, but it must be confessed that the circulation of the atmosphere, the basis on which all meteorology depends, remains more or less a hopeless puzzle.

The circulation is due to unequal cooling and heating of different parts of the earth's surface, about that there can be no doubt whatever, the difficulty comes in as soon as we try to see what should be the natural result of this cooling and heating.

Disregarding for the present the local circulation, the moving cyclones and anticyclones, the facts to be explained are the trade winds, the high-pressure belts lying poleward of the trades, the strong westerly winds of temperate latitudes and the low pressures on their poleward side.

It might seem, at first sight, as though a mathematical solution might be obtained, but the difficulties are very great. It is hardly likely that any solution could be satisfactory which did not take account of the humidity of the air, since the latent heat set free by the formation of rain is enormous, and when the humidity and the viscosity are added to the difficulties due to the friction of the earth's surface and the disturbance due to the earth's rotation, the difficulties seem to render a solution hopeless. Notwithstanding, it is a matter of regret that of the few men gifted with very exceptional mathematical ability who appear from time to time, none have made a special study of the subject. While full mathematical treatment is at present impossible certain elementary mechanical principles are fundamental, however, and must be understood before any intelligent discussion of the problem can be commenced. For the elucidation of these principles meteorologists are greatly indebted to Ferrel who, in my opinion, has done more for theoretical meteorology than any one else.

In considering the circulation of the atmosphere the first point that meets us is the effect of the earth's rotation upon a moving body, in this case upon the moving air. In one sense the effect is small, but the cumulative effect is very great. The following seems the simplest way of stating the effect. A body moving freely is subject to a continual change in its direction—in the Northern Hemisphere it turns to the right, in the Southern to the left. It does not matter which way it is moving, east or west, north or south, and it does not matter, within the limits of ordinary wind velocities, how fast it is moving; if moving freely, its direction of motion will gradually turn to the right [in the Northern Hemisphere]. The amount of change or the deviation is proportional to the time and to the sine of the latitude, and the change of direction in one hour is given in degrees by the expression 15 sin ϕ. Thus in latitude 45°, since sin 45° = 0.71 the change per hour is $10\frac{1}{2}°$, and a little under 9 hours, suffices to turn, in the Northern Hemisphere, an east wind into a south, or in the Southern Hemisphere into a north wind.

Suppose then that a place, *A*, lies north of place *B*, and that for some reason the barometer at *B* is lower than at